In: Edwards, M. Boyd, comp. 1995. Proceedings of the eighth biennial southern silvicultural research conference; 1994 November 1-3; Auburn, AL. Gen. Tech. Rep. SRS-1. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 573-580.

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SINGLY APPLIED HERBICIDES FOR SITE PREPARATION AND RELEASE OF LOBLOLLY PINE IN CENTRAL GEORGIA[1]

James H. Miller and M. Boyd Edwards[2]

Abstract—Separate studies were installed to evaluate site-preparation and release herbicide treatments for loblolly pine (*Pinus taeda* L.). Tests were at four locations each on the Piedmont and Coastal Plain of central Georgia. Six herbicide treatments were tested for pre-planting site preparation and seven treatments were applied in the third growing season for over-the-top release, both with untreated checks. Most herbicides were applied at maximum labeled rates. Six years after site preparation, per-acre pine volumes differed significantly ($p \leq 0.05$) among treatments as follows: Velpar® = Pronone® > Tordon® = Roundup® > Garlon® = Banvel® > check. Four full growing seasons after release, Arsenal® and Pronone treatments produced greater volumes than Roundup and check treatments and greater than all other treatments after 5 years. Because some release treatments grew less pine volume than the checks, proper release prescriptions appear more critical than site-preparation prescriptions.

INTRODUCTION

The use of herbicides for pine site preparation and release is increasing in southern forestry, especially as tank-mix applications. At the same time, little is understood about the control capabilities of the separate herbicides and their influence on pine and vegetative regrowth. A clearer understanding of each herbicide applied separately could result in more effective tank mixes.

This study was exploratory with tests on a wide range of sites to evaluate herbicides, in most cases applied singly, for both site preparation and pine release of loblolly pine (*Pinus taeda* L.). Pine growth was the primary focus. The practical objective of this cooperative research with the Georgia Forestry Commission was to identify herbicides suitable for reforestation by non-industrial private forest landowners after intensive harvesting of pines and hardwoods and small-diameter fuelwood. The Commission has long promoted the use of fuelwood as an alternative energy source. Prior reports from this research evaluated the projected growth and economics of the site preparation and release treatments (Busby and others 1993, Busby and Haines 1994) and floristic changes after the release treatments (Boyd and others 1994).

METHODS

Separate studies were installed to evaluate herbicide treatments for site preparation and for release of loblolly pine. Four locations were used with each: two in the Piedmont and two in the Coastal Plain of central Georgia (table 1). All test locations had been harvested for fuelwood to a 4-inch d.b.h. limit after commercial clearcuting, leaving few residual trees and maximum hardwood resprouts. For both treatment types, a randomized complete block design used locations as blocks. There were five blocks for the site-preparation study with two blocks established at the Piedmont location (McElroy) to include an eroded and non-eroded phase of a Piedmont soil. There were four blocks for the release study, but one block was destroyed due to an over-spray with a herbicide in the fourth growing season after treatment, which will be reflected in the analysis.

The prevalent hardwood species on these research areas were sweetgum (*Liquidambar styraciflua* L.), southern red oak (*Quercus falcata* Michx.), water oak (*Q. nigra* L.), black tupelo (*Nyssa sylvatica* Marsh.), red maple (*Acer rubrum* L.), flowering dogwood (*Cornus florida* L.), black cherry (*Prunus serotina* Ehrh.), persimmon (*Diospyros virginiana* L.), and pignut hickory (*Carya glabra* (Mill.) Sweet). Prevalent shrubs were hawthorn (*Crataegus* spp.), blueberry (*Vaccinium* spp.), and southern bayberry (*Myrica cerifera* L.).

Six herbicide treatments were tested for pre-planting site preparation and seven treatments were applied in the third growing season for over-the-top release. Check plots were established at each location. High labeled rates or affordable rates (i.e., for Tordon 10K and Oust + Velpar L) were used, applied at what is generally considered optimum or near-optimum timings.

[1]Paper presented at the Eighth Biennial Southern Silvicultural Research Conference, Auburn, AL, Nov. 1-3, 1994.

[2]Research Ecologist, Southern Forest Experiment Station, Auburn University, AL, and Research Ecologist, Southeastern Forest Experiment Station, Dry Branch, GA.

The site-preparation treatments were:

Herbicides	Pounds of active ingredient (product) per acre	Applied in
Velpar L	2.5 to 3.5 hexazinone (1.25 to 1.75 gal)	May
Pronone 10G	2.5 to 3.5 hexazinone (25 to 35 lb)	May
Tordon 10K	3 picloram (30 lb)	June
Garlon 4	4 triclopyr (1 gal)	June
Banvel + Banvel 720	4 dicamba + 4 2,4-D (0.5 + 2 gal)	June
Roundup	4 glyphosate (1 gal)	August

Tordon 10K pellets are no longer manufactured, but the liquid formulation of picloram (Tordon K) is. Tordon K at 1.5 gal/acre would equal Tordon 10K at 30 lb/acre.

Also, the glyphosate formulation presently labeled for southern forestry is Accord, which is comparable to Roundup in concentration and therefore rate. The release treatments were:

Herbicides	Pounds of active ingredient (product) per acre	Applied in
Pronone 10G	0.9 to 1.5 hexazinone (9 to 15 lb)	April
MCI 54 Pellets®	(a) 2/3 the Pronone a.i. rate (20 to 33 lb)	April
	(b) 3/4 the Pronone a.i. rate (22 to 37 lb)	April
Velpar L	1.0 to 2.25 hexazinone (2 to 4.5 qt)	May
Oust® + Velpar L	0.09 sulfometuron (2 oz) +0.5 hexazinone (1 qt)	May
Arsenal AC	1.0 imazapyr (1 qt)	June
Roundup	2.0 glyphosate (2 qt)	September

The combination of Oust and Velpar was an experimental release treatment to test pine response to only herbaceous plant control at these rates.

Hexazinone rates (Pronone 10G and Velpar L) were prescribed according to soil texture and percent organic matter as specified on the labels. Thus, higher hexazinone rates were applied to Piedmont locations and lower rates to the Coastal Plain locations. An experimental product that is no longer manufactured, MCI 54 Pellets, was a concentrated nitrogen fertilizer (66 percent by weight) and contained 3 percent hexazinone. MCI rates were based on Pronone rates but were lower, assuming that hexazinone would be more effective when used with nitrogen fertilizer (and would have a higher price per pound of active ingredient (a.i.), requiring a lower rate to be competitively priced).

It was assumed that 1 inch of rainfall is required to activate the soil-active pelleted hexazinone and picloram herbicides (Pronone 10G, MCI 54, and Tordon 10K Pellets) and 0.5 inch to activate the liquid hexazinone treatments (Velpar L and Oust + Velpar L). Following these assumptions, Pronone 10G and Tordon 10K were activated 22 to 24 days after site preparation applications, while Pronone and MCI 54 Pellets were activated 16 to 19 days after release applications. Liquid hexazinone treatments (Velpar L and Oust + Velpar L) were also activated at 22 to 24 days after site preparation applications and on the day following release applications.

Treatments were applied on 0.5- to 2-acre plots using either a crawler-tractor-mounted sprayer equipped with a Boomjet cluster nozzle (45-ft effective swath) or an Omni spreader (85-ft effective swath). Both systems had application control systems that maintained test rates as ground speed varied (Miller 1988, 1991). The nozzle height was adjusted for each location to apply the herbicide mixture into the sides and over-the-top of most vegetation, although side shielding is always a problem with ground spray applications (Miller 1988). It is now recognized that the Boomjet cluster nozzle produces an uneven, within-swath distribution (Miller 1990), which may make foliar herbicides less effective (e.g., Roundup and Garlon), but be less critical for herbicides with soil-activity (e.g., Velpar, Arsenal, and Banvel). Sprays were applied at 40 gal/acre total herbicide-water mixtures, except for Roundup which was applied at 25 gal/acre (per label instructions). A 5-ft swath overlap was used for site preparation applications, while edge-to-edge swaths were for with release applications--assured by surveyed flagging stations and ground guidance.

At the site-preparation locations, harvesting was done at various times before treatment, from just 2 months (Hill tract) to 7 years (McElroy tract), allowing observations on treatment timing relative to harvest. Site-preparation treatments were applied from May to August 1984, and all plots including the checks were prescribe-burned in late October or early November 1984. Genetically improved loblolly seedlings were machine planted on a 6-by-9-ft spacing in February or

Table 1.–Location and site and soil characteristics of Georgia study areas.

Tract	County	Province	Site index[a]	Soil and slope
		Site preparation		
Ellington	Laurens	Coastal Plain Sandhills	70	Ailey loamy sand, 8-17 percent slope, and Orangeburg loamy sand, 12-17 percent slope.
Grimsley	Twiggs	Coastal Plain	85	Tifton fine sandy loam, 2-5 percent slope and Norfolk loamy sand, 2-5 percent slope.
Hill	Twiggs	Coastal Plain	80	Norfolk loamy sand, thin solum, 2-5 percent slope, and Tifton fine sandy loam, 2-5 percent slope.
McElroy 1	Monroe	Piedmont	80	Gwinnett sandy clay loam, 2-15 percent slope.
McElroy 2	Monroe	Piedmont	75	Gwinnett sandy clay loam, 6-15 percent slope, eroded.
		Release		
Patton	Twiggs	Coastal Plain Sandhills	70	Ailey loamy sand, 8-17 percent slope.
Duggins	Laurens	Coastal Plain	85	Cowarts loamy sand, 2-5 percent slope, Fuquay loamy sand, 0-5 percent slope, Lucy loamy sand, 0-5 percent slope, and Orangeburg sandy loam, 5-8 percent slope, eroded.
Robinson	Monroe	Piedmont	75	Gwinnett sandy clay loam, 6-15 percent slope, eroded.
Davis	Monroe	Piedmont	80	Cecil sandy loam, 6-10 percent slope.

[a]Base age 50, with values derived from on-site soil series identification and from the Soil Conservation Service data base.

early March 1985. Fifty planted seedlings per plot were measured for total height and groundline diameter (g.l.d.) after 1, 2, 3, and 5 growing seasons. After the sixth growing season, total height and d.b.h. were measured. Measurements for both studies were made to the nearest 0.1 ft for heights, 0.01 in. for g.l.d., and 0.1 in. for d.b.h.

Release treatments were applied during the 1985 growing season. The planted, improved loblolly seedlings were in their third growing season in the field at the time of treatment. The seedlings had been planted on a 6-by-9-ft spacing after prescribed burning. Before treatment, 80 pine seedlings per plot were randomly selected for measurement: 20 in each of four woody competition classes:

- Class 1. The seedling had no woody competitor near it that, when bent over, could touch the upper half of the seedling's main stem.
- Class 2. The seedling had one woody competitor near it that could touch the upper half.
- Class 3. The seedling had woody competitors on two sides that could touch the upper half.
- Class 4. The seedling had woody competitors on three sides that could touch the upper half of the seedling's main stem.

This stratified sampling provided a population of measurement seedlings with competition conditions in fixed proportions. This approach minimized a major source of experimental error associated with release studies: unequal competition conditions at the start of the study. Height and g.l.d. were measured on the 80 seedlings before and after the treatment growing season and then 1, 3, and 4 full growing seasons after treatment (FGSAT). At 5 FGSAT, height and d.b.h. were measured. MCI treated trees were not measured past 4 FGSAT.

For the release study, competition cover was estimated in October 1986, at the end of 1 FGSAT. Woody, non-pine cover was ocularly estimated on two 33-by-33-ft sample sub-plots that were systematically positioned within each main plot. These sub-plots were quartered and estimates were made in each quarter for herbaceous cover by growth forms and the amount of bareground.

A per-acre volume index was calculated for the loblolly pine seedlings, as:

g.l.d.^{2} (or d.b.h.^{2}) X height X survival X planting density.

Data were analyzed by analysis of variance, except that an analysis of covariance was used for release pine data using before-treatment measurements as the covariate. Duncan's multiple range test was used to compare means. Differences were considered significant at the 0.05 level for a Type I error.

RESULTS AND DISCUSSION

Site Preparation

Pine survival averaged across sites was 89 to 95 percent after the first year and 80 to 89 percent after six years, including the burned-only checks, and did not vary by treatment. This high survival resulted from the good quality of seedlings and planting operation, since below-average rainfall occured during the first four growing seasons. The lowest survival, 42 percent, occurred on the Sandhill site after applications of Tordon, where seedlings had toxicity symptoms for up to 2 years. Residual picloram toxicity has long been recognized as a problem on sandy soils.

Significant differences (a<0.05) among treatments were evident in per-acre pine volumes after 5 and 6 years, according to the following interpretation of the Duncan's analysis: Velpar = Pronone > Roundup = Tordon > Garlon = Banvel > Check (table 2 and fig. 1). After 6 years the per-acre volume for the Velpar treatment was about 6 times greater than the check and the Banvel treatment was 2.8 times greater. Velpar and Pronone (hexazinone treatments) yielded the greatest or second-greatest volumes after 6 years on most sites, while Tordon was second on the Grimsley tract and Roundup was second on the McElroy2 tract (eroded Piedmont). Pine growth response (and observed control) on the recently logged Hill tract was similar to that at other locations that had 1 to 7 years to regrow before treatment.

Greatest overall pine growth occurred at the Grimsley tract on the Coastal Plain and the lowest growth was on the Ellington tract on the Coastal Plain Sandhills. The extraordinary pine volume growth on the Grimsley site after Velpar application (1,031 ft^3/acre after 6 years) was due to 3 years of complete herbaceous and woody control on this poorly drained site, exceptional for residual control. Another soil-active herbicide, Tordon, yielded the second most growth on this site, indicating that surface moisture may influence the length of residual activity.

Release

In October of the year after treatment, woody cover was 10 to 20 percent less on the Arsenal, Velpar, and Roundup treatments than on the others (table 3). Grasses were least on Arsenal, Roundup, and MCI 2/3 treatments, with a concomitant increase in forbs where Arsenal and Roundup were used. Grasses are severe competitors of pine seedlings for soil moisture, while forbs are thought to be less competitive (Morris and others 1993). MCI 2/3 treatment also had the most bare ground, but was different only from the check at the 0.05 level. No consistent differences in vines were detected.

Table 2.–Site-preparation treatments: volume index (ft^3/ac, using d.b.h.) by location in the sixth growing season after treatment.

	Coastal Plain			Piedmont		
Treatment	Ellington	Grimsley	Hill	McElroy1	McElroy2	Mean[a]
Velpar	560[b]	1,031	483	518	280	575 a
Pronone	423	574	510	716	473	539 a
Roundup	254	572	295	219	419	351 ab
Tordon	42	700	340	369	285	347 ab
Garlon	94	471	293	385	196	288 bc
Banvel	223	332	219	399	153	265 bc
Check	81	72	124	105	91	95 c
MEAN	240	536	323	387	271	
ROOT MEAN SQUARE ERROR	351.5					

[a]Means in a column followed by the same letter are not significantly different at the 0.05-level of probability as determined by Duncan's Multiple Range test.
[b]A double underline highlights the greatest pine growth on a location and a single underline highlights the second-greatest growth.

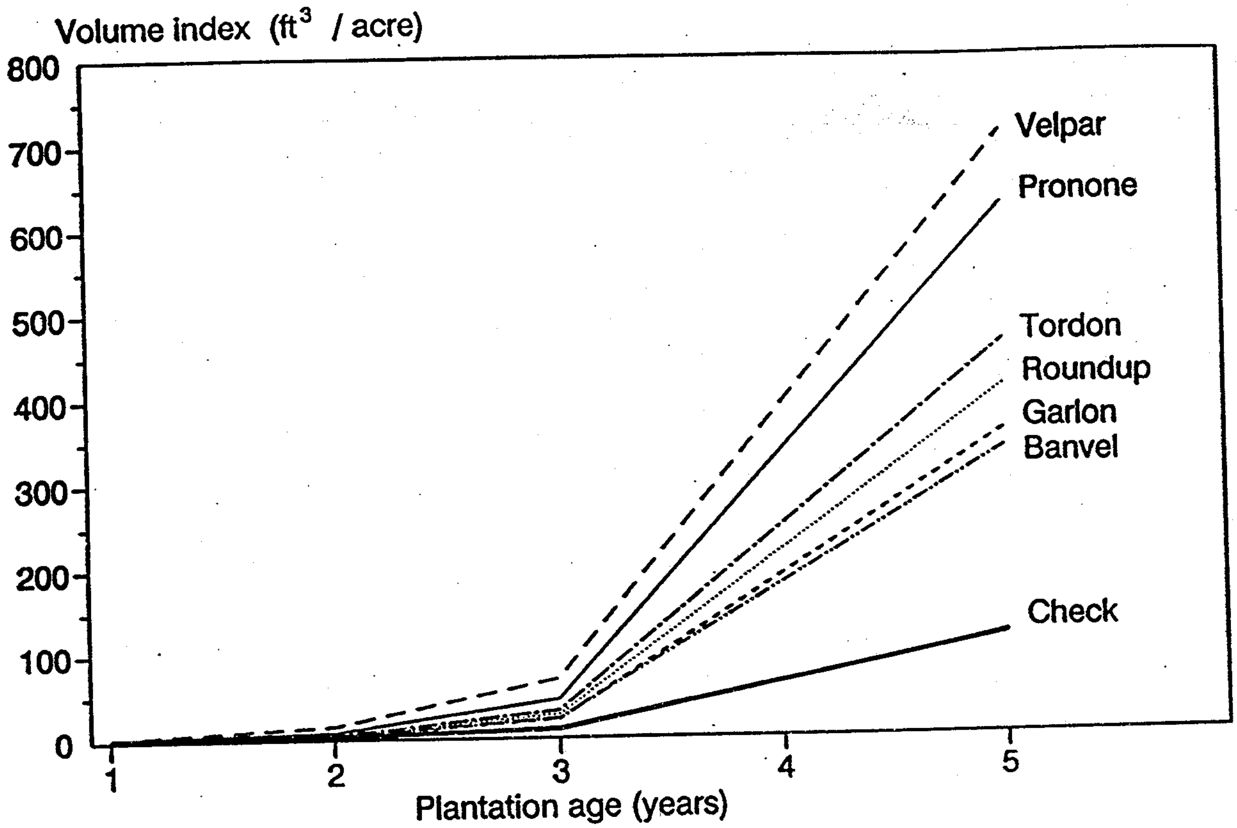

Figure 1.–Loblolly pine volume index (using g.l.d.) after herbicide site preparation treatments.

Table 3–Pine release: mean cover estimates and the amount of bare ground (percent) in October of the growing season following treatment

Treatment	Woody cover	Grass cover	Forb cover	Vine cover	Bare-ground
Arsenal	12 c[a]	26 bc	41 a	4 a	14 ab
Pronone	30 ab	46 ab	10 b	12 a	13 ab
Velpar	25 bc	46 ab	15 b	10 a	15 ab
MCI 2/3	38 ab	27 bc	14 b	17 a	19 a
MCI 3/4	38 ab	41 ab	19 b	14 a	9 ab
Oust+Velpar	37 ab	39 ab	7 b	24 a	11 ab
Roundup	23 bc	18 c	44 a	4 a	17 ab
Check	42 a	50 a	15 b	6 a	5 b
ROOT MEAN SQUARE ERROR	10.2	12.7	12.5	14.2	7.5

[a]Means in a column followed by the same letter are not significantly different at the 0.05-level of probability as determined by Duncan's Multiple Range test.

Pine survival was often reduced by release treatments, with Velpar causing the most mortality–an average 37-percent decrease compared to the check (table 4). Velpar toxicity was most pronounced at the higher-rate sites, 2.5 to 4.5 qt/acre, at Davis, Robinson, and Duggins. Seedlings at the Davis site were most exposed to direct application of herbicide because of the scattered amounts of hardwood competition, resulting in only 27 percent survival. Most herbicides caused some degree of pine toxicity, as evidenced by survival values at particular sites (table 4).

Table 4.--Release treatments: percent survival by location at the end of the growing season of treatment

Treatment	Coastal Plain		Piedmont		Mean[a]
	Patton	Duggins	Davis	Robinson	
Arsenal	97	93	74	97	87 a
Pronone	84	86	73	56	74 a
Velpar	83	59	27	58	55 b
MCI 2/3	89	86	89	93	88 a
MCI 3/4	88	64	78	83	74 a
Oust+Velpar	91	78	91	94	84 a
Roundup	90	85	76	87	83 a
Check	100	89	97	94	91 a
ROOT MEAN SQUARE ERROR	12.1				

[a]Means in a column followed by the same letter are not significantly different at the 0.05-level of probability as determined by Duncan's Multiple Range test.

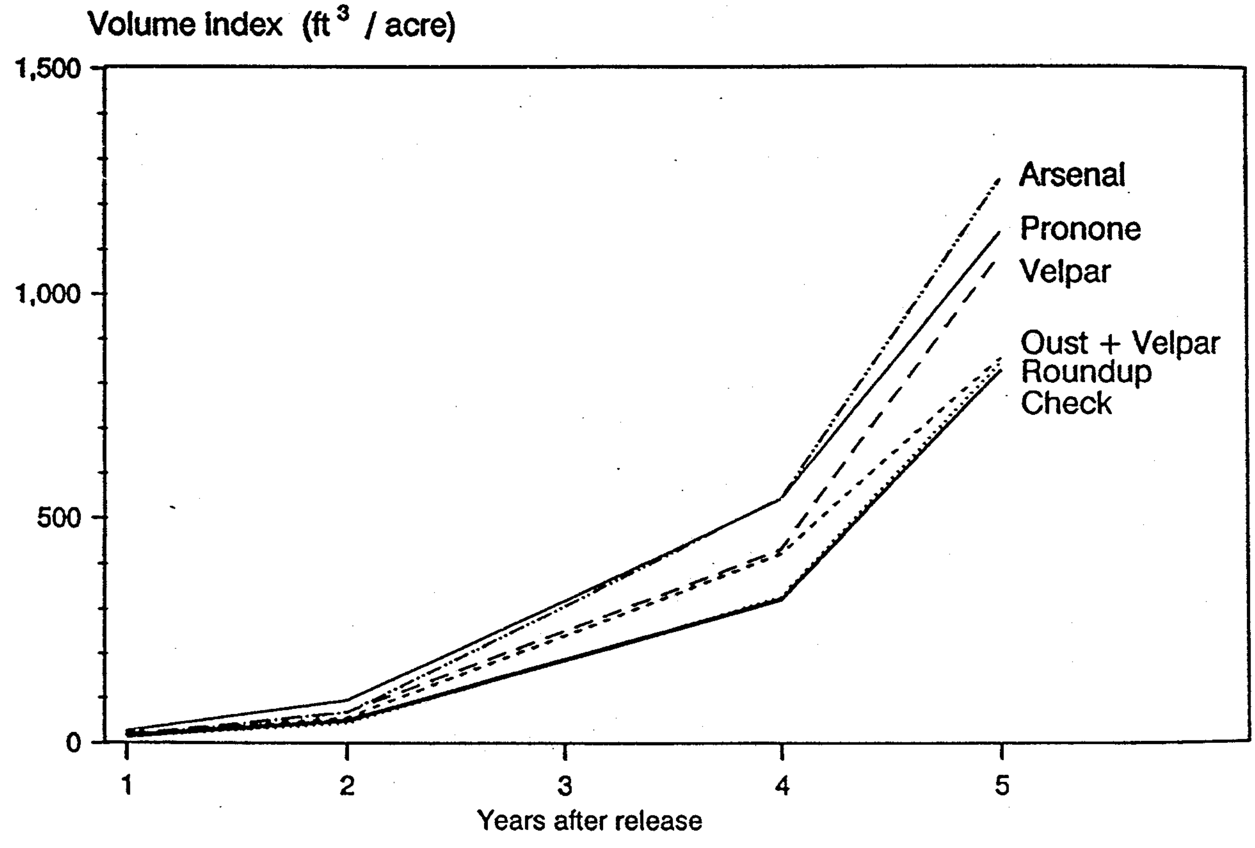

Figure 2.--Loblolly pine volume index (using g.l.d.) after herbicide release treatments.

The response to over-the-top release treatments is the combined result of phytotoxic injury, recovery time, and growth increase prompted by competition control. Pine growth response also varies according to the timing and degree of herbaceous and woody competition control (Miller and others 1991). Because of these different influences, pine response is more variable after release treatments than after pre-planting site-preparation treatments (compare Figures 1 and 2).

Arsenal and Pronone release treatments produced greater volumes at 4 FGSAT than the Roundup and check treatments (table 5) and greater volumes at 5 FGSAT than all other treatments (table 6). The highest yielding treatments varied widely by location. In

Table 5.--Release treatments: volume index (ft^3/ac., using gld) by location, four full growing seasons after treatment (seven growing seasons after planting)

Treatment	Coastal Plain		Piedmont		Mean[a]
	Patton	Duggins	Davis	Robinson	
Arsenal	180	943	318	740	546 a
Pronone	141	1,308	372	346	542 a
Velpar	232[b]	941	236	322	433 ab
MCI 2/3	135	644	669	354	450 ab
MCI 3/4	228	612	656	222	429 ab
Oust+Velpar	118	692	448	434	423 ab
Roundup	111	637	172	398	330 b
Check	88	705	171	323	322 b
MEAN	154	810	380	392	
ROOT MEAN SQUARE ERROR	179.1				

[a]Means in a column followed by the same letter are not significantly different at the 0.05-level of probability as determined by Duncan's Multiple Range test.
[b]A double underline highlights the greatest pine growth on a location and a single underline highlights the second-greatest growth

Table 6.--Release treatments: volume index (ft^3/ac., using dbh) by location, five complete growing seasons after treatment (eight growing seasons after planting)

Treatment	Coastal Plain		Piedmont	Mean[a]
	Patton	Duggins	Robinson	
Arsenal	128[b]	1,409	1,084	874 a
Pronone	95	1,808	588	831 a
Velpar	182	1,186	459	609 b
Oust+Velpar	49	963	534	515 b
Roundup	83	794	687	522 b
Check	38	1111	556	569 b
MEAN	95	1212	651	
ROOT MEAN SQUARE ERROR	179.1			

[a]Means in a column followed by the same letter are not significantly different at the 0.05-level of probability as determined by Duncan's Multiple Range test.
[b]A double underline highlights the greatest pine growth on a location and a single underline highlights the second-greatest growth.

general, the control of only herbaceous vegetation using the Oust + Velpar mixture produced no significant growth increases by 4 and 5 FGSAT. Similar to the site-preparation test, overall growth was best on a Coastal Plain site (Duggins) and the least on the Sandhill site (Patton tract).

At all locations except the Patton Sandhill tract, one or more treatments produced pine growth that was no better than the checks. This indicates that the selection of the best herbicide is more critical for release than for site preparation, where all but one treatment produced better than the checks. Also, timing of application relative to pine growth flushes is critical. The poor performance of the Roundup treatment must be partially due to the fact that August rains after a dry, early summer resulted in abundant growth flushes just before the September 1 applications. Most new terminal and lateral leaders were killed.

CONCLUSIONS

Both site-preparation and release treatments increase pine volume growth on intensively harvested lands when the correct herbicide is prescribed and applied at the optimum time. Both treatments, when properly done, should be profitable investments as well (Busby and others 1993). It is clear that pine can grow faster after site preparation treatments than after release and thus site preparation is projected to yield greater economic returns (Busby and others 1993).

Futhermore, the lower rates of herbicide treatment used for release did not significantly alter the plant community and floristic diversity or adversely affect wildlife habitat 7 years after treatment (Boyd and others 1994). It is assumed that the higher rate site-preparation treatments respond similarly, but further study of the floristic changes are needed.

ACKNOWLEDGMENT

This research was made possible through a grant and cooperation from the Georgia Forestry Commission.

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